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G-force tests answer color-fading questions

by Bobbie Mixon Jr., Aeronautical Systems Center

WRIGHT-PATTERSON AFB, OHIO — They say a picture is worth a thousand words. But when that picture is composed of kaleidoscopic color images on a fighter aircraft's cockpit display, its details can become difficult to discern as a pilot pulls higher and higher G's — especially when the picture's colors keep "changing."

According to Air Force research, increased G forces can cause eye-level blood pressure to drop and color vision to fade, dramatically altering the perception of the picture before a pilot, and potentially disrupting the pilot's ability to discern informational cues on the cockpit's display. That's why scientists here at the Air Force Research Laboratory have been using the Dynamic Environment Simulator, a man-rated, three-axis centrifuge, to investigate why colors fade at high G and whether a pilot's performance is affected by such fading.

TESTING THE COLORS — Major Steve Alsing, a Ph.D. student at the Air Force Institute of Technology here and a former KC-135 pilot, participates in color-vision tests in the Dynamic Environment Simulator at the Human Effectiveness directorate.

For years, researchers have known about the effects on eyesight of "gray out" and blackout associated with the collapse of peripheral vision at high G's, but traditional green and black, monochrome displays presented few color-related performance problems during these episodes due to the absence of color-coded information. Advances in display technology, however, have resulted in more vibrant cockpit indicators, making questions related to color vision more relevant.

The answers are useful to military aviators because pilots depend on the ability to discern and identify colors when performing many cockpit tasks, such as reading a moving map display, or understanding threat-warning and situational indicators.

According to Dr. Tamara Chelette, a biomedical engineer heading the color study for AFRL's Human Effectiveness directorate here, some results are in.

"At high G, the eye tends to first lose cyan, a light blue color, while yellow and green tend to blend together and become indistinguishable."

Previous anecdotal evidence led to a belief that perception of some colors changed during periods of high-G flight; red was seen as black, for example. However, laboratory testing at AFRL scientifically proved such color-vision changes for the first time.

Researchers have determined that the loss of color vision is not necessarily due to the colors themselves, but is caused by the luminance contrast used to display a particular hue.

"Luminance is an objective measure that relates to the human perception of brightness," said Dr. David Post, a human factors engineer and color expert for AFRL. Luminance contrast, a ratio of two luminances, measures how well something stands out against its background.

"We found that the color-fading effect is directly related to a color's luminance contrast," said Post, who co-investigated the study. "Specifically, the lower a color's contrast, the more vulnerable it is to fading under G."

Luminance converts a measure of light energy into a number that relates to the light's brightness in much the same way that the decibel converts a measure of sound energy into a number that relates to the sound's loudness. In both cases, human sensitivity to different wavelengths is used to yield a number that better describes the human perception. The luminance contrasts that can be produced on a cockpit's display depend on the colors used. Color displays produce color by mixing red, green and blue light. Green usually has the highest peak luminance and blue has the lowest. When using a dark gray background, for example, green symbols can be presented at higher contrast than blue symbols, making the green symbols less likely to fade and the blue symbols more likely to fade.

Two patches of color having similar luminances, seen side by side, tend to blend together due to their low contrast, as in yellow and green.

In other cases, low contrast symbols tend to blend into their background, as when cyan is contrasted against a white background.

Understanding these effects and the role of display limitations will be important to designers of aircraft cockpit symbology, who use standardized computer symbols and situational indicators. Typically, red symbols identify an enemy, green a friend and yellow an unknown.

Testing has shown that color-coded information in the cockpit improves reaction times and decreases error rates, making the use of multicolored displays more likely in future aircraft, Chelette said.

"We don't know if anything needs to be changed," Chelette said about choosing colors for cockpit displays. "In fact, right now we don't think anything needs to be changed at all. However, designers will need to be aware of this information as they create new, more colorful, more up-to-date displays."

The study's preliminary findings come from two different types of experiments that used Air Force guidelines as a starting point for colors in electronic cockpit displays. In the first series of tests, subjects were placed in the centrifuge and spun up to nine G's, or nine times the force of gravity, and asked to perform a simple task: Identify colors seen on a screen inside the centrifuge's cab.

Five colors were used: red, blue, green, yellow and neutral, which was a grayish color, and three luminance contrasts, corresponding to day, night and twilight.

"Test subjects performed really well in these experiments," Chelette said. "They basically gave consistent responses when colors faded or objects disappeared."

The next series of tests required subjects to use more of their cognitive abilities. Two of the five colors were in play at the same time during any one 30-second trial. The test subject was required to recognize which color had the higher number of targets and press a button on a hand-held controller to mark an answer.

Researchers are still analyzing the data from these tests to see if there is a possibility of delayed reaction time discerning any one color.

"We don't understand the basic science yet," said Colonel (Dr.) Rick Allnutt, chief flight surgeon for AFRL. "We're not sure if this loss of color vision has to do with the lower blood levels in the eye at high G, or some other factor.

"What we have been able to determine is that the colors currently in use are satisfactory to do the job that needs to be done. At this point, I think we're safe in saying that."

Next, an Air Force technical report will be created based on these color-vision tests for use by other researchers, military flight surgeons and industry. **@**